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VEGETABLES AS A POTENTIAL SOURCE OF NUTRACEUTICALS AND PHYTOCHEMICALS: A REVIEW

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ABSTRACT

About 3 billion people in the world are malnourished due to imbalanced diet. Vegetables are the essential part of balanced diet since they are good source of phytonutrients and nutraceutical compounds. Vegetables are rich source of carbohydrates, proteins, vitamins and minerals, hence known as protective foods. They also give health protection on account of the presence of secondary metabolites of therapeutic importance. The most important phytonutriceuticals in vegetables that have biological activity against chronic diseases are: vitamins, minerals, dietary fiber, organosulfur compounds (glucosinolates and thiosulfides) and flavonoids. Each vegetable contains a unique combination of phytonutriceuticals. A great diversity of vegetables should be eaten to ensure that individual's diet includes a combination of phytonutriceuticals and to get all the health benefits. Phytochemicals are broadly described as phytoestrogens, terpenoids, carotenoids, limonoids, phytosterols, glucosinolates, polyphenols, flavonoids, isoflavonoids and anthocyanidins. They have tremendous impact on the health care system and may provide medical health benefits including the prevention and/ or treatment of diseases and physiological disorders. The present review has been devoted to get acquaint with nutraceutical value of vegetables.

KEYWORDS: Vegetables, Nutraceuticals, Phytochemicals, Edible Pigments, Human Nutrition

INTRODUCTION

Nutraceutical, a portmanteau of the words "nutrition" and "pharmaceutical", was coined in 1979 by Dr. Stephen L. DeFelice, founder and chairman of the Foundation of Innovation Medicine (FIM) (Crawford, New Jersey) [18]. It is a food or food product that provides health and medical benefits, including the prevention and treatment of disease. They are the product isolated or purified from foods, and generally sold in medicinal forms not usually associated with food and demonstrated to have a physiological benefit or provide protection against chronic disease.

Phytonutriceuticals are all the chemical compounds derived from plants that have health-promoting properties. Phytochemicals impart health benefits to humans in addition to those provide by vitamins and minerals alone. Most phytochemicals have antioxidant activity and protect our cells against oxidative damage.

Presently the two major concerns of developing countries are to overcome hunger and malnutrition. About 43.5 % children in India under the age of five years are chronically malnourished. Consumption of vegetables is generally considered to be associated with several positive effects on health. It has been shown that low consumption of fruit and vegetables is related to more cardiovascular disease and cancer [21, 28, 29, 30]. The diversified and highly nutritive vegetables are of great importance in alleviating malnutrition. The presence of phytochemicals, in addition to vitamins and

pro-vitamins, in fruits and vegetables has been considered of crucial nutritional importance in the prevention of chronic diseases, such as cancer, cardiovascular disease and diabetes [10]. Green leafy vegetables have been used as medicine since ancient times and have been playing a very important role in our diet and nutrition. Green leafy vegetables (GLV's) are rich source of vitamins such as beta carotene, ascorbic acid, folic acid and riboflavin as well as minerals such as iron, calcium and phosphorous. Many leafy vegetables especially, amaranth, fenugreek, palak and spinach has attained commercial status and its cultivation is wide spread in India. Because of their low production cost and high yield, GLV's are considered to be one of the cheapest vegetables in the market and it could be rightly described as 'poor man's vegetables [47]. They are the most readily available sources of carbohydrates, fats, important proteins, vitamins, minerals, essential amino acids, and fibers [40]. Being a photosynthetic tissue, leafy vegetables have higher levels of vitamin K when compared with other fruits and vegetables due to direct involvement of vitamin K (phylloquinone) in photosynthesis process [4]. Leafy vegetables are natural source of antioxidants and rich in phytochemicals [12].

NUTRACEUTICALS/PHYTOCHEMICALS/PIGMENTS IN VEGETABLES

Carotenoids for Colon Cancer

Carotenoids are a major class of secondary metabolites with many biological activities such as free radical scavenging properties, skin tone improvement and potential for cancer treatment. Generally carotenoids are classified into two main subclasses such as hydrocarbon carotenoids including β-carotene, α-carotene, lycopene and oxycarotenoids which include lutein and zeaxanthin, as well as other compounds. Carotenoids have many applications in the clinical and commercial fields. β-Carotene has been shown to be efficient in controlling cellular damage from free radicals. Secondary metabolites can influence and effectively react with free radicals in the inner part of the cell membrane. The natural compounds have been more effective in maintaining membrane integrity and antimutagenic properties [51].The unsaturated nature of lycopene has potential efficiency to provide free radical scavenging activity and inhibit cancer progression. Lycopene is present in various dietary sources such as tomatoes, grapes and papaya. Carotenoids are used for the prevention of colon and gastrointestinal cancer [52]. Other phytochemicals such as xanthophyll, astaxanthin, cryoptoxanthin and zeaxanthin metabolites have been used for the treatment of colon cancer.

Beta-Carotene

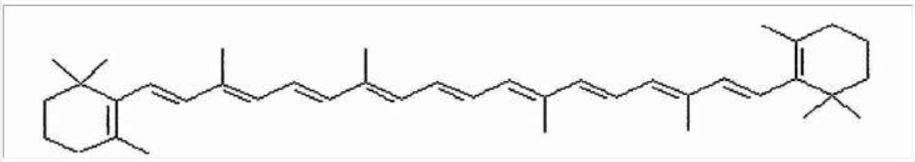

Figure 1

NUTRACEUTICAL COMPOUNDS IN VEGETABLES

Table 1

Nutraceuticals	Vegetables
Glucosinolates, Sulforaphane	Cole crops
Lycopene	Tomato and other Solanaceous vegetables, Watermelon
Silymarin	Artichoke
Vit C	Cabbage, Croccoli, Green leafy vegetables (GLV)
Vit E	GLV

Table 1: Contd.,

Allyl Sulphides	Onion and Garlic
Vit A	Carrot, Pumpkin, Cantaloupe
Vit C	Bitter gourd, Capsicum
Folates	GLV
Alliin, Methiin	Alliums
Quercetin	Onion and Garlic
Kaempferol, Myricetin, Fisetin	Onion, Lettuce, Endive, Horse Radish
Luteolin	Celery, Broccoli
Apigenin	Celery, Cabbage and Lettuce
Isoflavonoids	Legume vegetables, Broccoli and Okra
Genistein and Daidzein	Soybean
Glucoraphanin	Red cabbage and Broccoli
Glucobrassicin, Progoitrin, Gluconasturtiin	Broccoli
Glucoerucin, Glucoraphanin	Turnip and Rutabaga
Lysine, Chlorgenic Acid	Potato
Caffeic acid, Chlorgenic Acid	Eggplant
Nasunin	Eggplant
Angelicin, Xanthotoxin	Parsnip
Ferulic Acid, Betanin	Beet root
Anthocyanin and Chlorgenic Acid	Sweet Potato
Rutin	Asparagus, Green Chilli
Patuletin, Spinacetin	Spinach
2″-xyloside vitexin and 6″-malonyl-2″-xyloside vitexin	Swiss Chard
Betanin	Beet, Chard
Capsaicin	Red Chilli
Carnitine	Shatavari
Curcumin	Turmeric
Hesperitin	Green Vegetables
Lignan	Soybean and Broccoli
Nattokinase	Soybean
Resveratol	Red Onion

Antioxidant Vitamins

Vitamins like vitamin C, vitamin E and carotenoids are collectively known as antioxidant vitamins. These vitamins act both singly as well as synergistically for the prevention of oxidative reactions leading to several degenerative diseases including cancer, cardiovascular diseases, cataracts etc [53]. These vitamins are abundant in many fruits and vegetables and exert their protective action by free-radical scavenging mechanisms. Vitamin E and selenium has a synergistic role against lipid peroxidation. Vitamin C, better known as ascorbic acid donates hydrogen atom to lipid radicals, quenches singlet oxygen radical and removes molecular oxygen.

Carotenoids

Carotenoids are lipid-soluble, yellow–orange–red pigments found in all higher plants and some animals. Oxy-carotenoids or xanthophylls such as lutein and zeaxanthin and non-oxy carotenoids (hydrocarbon carotenoids) or carotene such as beta carotene and lycopene has been identified among more than 600 carotenoids found in natural sources [22]. Carotenoids can be divided into carotenes containing only carbon and hydrogen, and xanthophylls made up of carbon, hydrogen, and oxygen. Carotenoids owe their name to carrots (*Daucus carota*), and xanthophyll is derived from the Greek

words for yellow and leaf [34]. Among vegetables, carrot is the single major source of β-carotene providing 17% of the total vitamin A consumption [1]. Apart from β-carotene, root is good sources of various other lipophilic antioxidants like lycopene and lutein. Red coloured carrot is typical to India [25] and predominantly cultivated in northern India for preparation of traditional sweet desert 'Halwa'. Anthocyanin rich black carrot variety cultivated in northern India, is used for preparation of traditional probiotic fermented beverage 'Kanji [20]. Sweet potatoes and Pumpkin are also regarded as one of the most nutritious vegetable crops. They are known to be an excellent source of vitamin A (orange-flesh types).

Lycopene

Being a precursor in the biosynthesis of β-carotene, lycopene can be expected to be found in plants containing β-caroten. The best-known sources of lycopene are tomatoes, watermelon, red cabbage, red peppers, carrot, guava, and pink grapefruit. This red colored pigment was first discovered in the tomato by Millardet in 1876. It was later named lycopene by Schunck [43]. Lycopene is also a potent neuroprotective [16], antiproliferative, anticancer [14], antiflammatory, cogntion enhancer [2] and hypocholesterolemic agent [39].

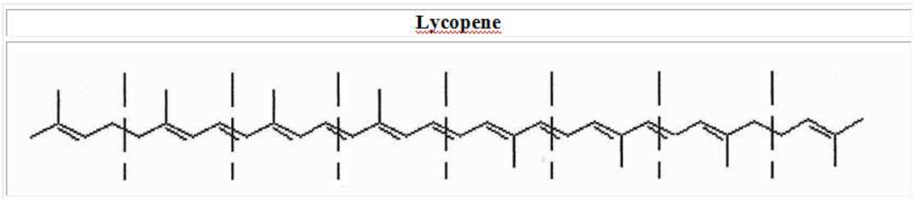

Figure 2

Lutein

Lutein is also a very common carotenoid. Commercially, the most interesting source is Aztec marigold (*Tagetes erecta*) in which lutein is primarily found esterified with saturated fatty acids *viz.*, lauric, myristic, palmitic, and stearic acid [6]. Lutein provides nutritional support to our eyes and skin. Its antioxidant activity counteracts radical damage. It is found in good amount in green leafy vegetables like broccoli, spinach, kale and lettuce etc.

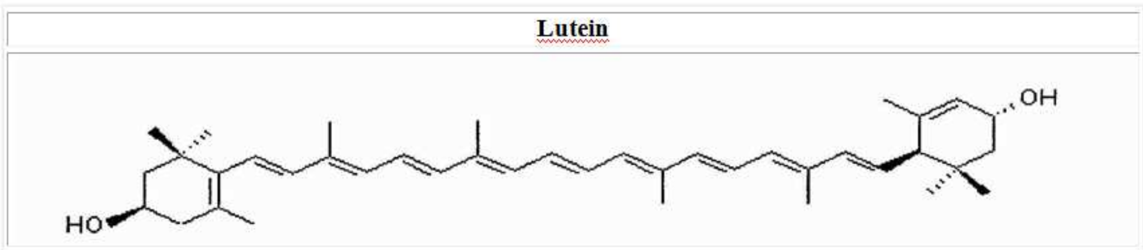

Figure 3

Phenols

Phenols comprise a large group of phytonutrients with profound importance in preventive medicine. Phenols have protective action against oxidative damage of tissues and inflammation. Flavonoids, anthocyanidines and isoflavones are major subclasses under phenolic group. One of the vegetables with a highest content in phenolics is eggplant (*Solanum melongena* L.) [15, 32, 42]. Because of this, eggplant is considered as a model vegetable crop for the improvement of nutraceutical quality [36]. The main phenolic compound of eggplant is chlorogenic acid (CGA), which is an hydroxicinnamic acid with multiple beneficial properties for human health [15]. CGA has displayed anti-oxidant,

anti-carcinogenic, anti-inflammatory, anti-obesity, cardioprotective, neuroprotective, and analgesic effects [36]. As a result, CGA plays a major role in the nutraceutical properties of eggplant [3]. The most important of these phenolic compounds in beans are flavonols quercetin and kaempferol, flavon apigenin and some phenolic acids (e.g. *p*-coumaric acid or ferulic acid).

Anthocyanins

Anthocyanins give rise to the blue–purple–red–orange color of flowers and fruits, in particular, of many plants. The name comes from two Greek words meaning flower and dark blue (and not the blue–green color we usually associate with cyan). The most important source of anthocyanins is grape pomace from wine production. Other important sources are red cabbage, elderberry, black currant, purple carrot, sweet potato, and red radish. Anthocyanin rich vegetables such as purple cauliflower, broccoli and black/purple carrots are gaining popularity due to their enhanced antioxidant activity. Radish and potato extracts have color characteristics very similar to those of Allura red [41].

Concentration of Anthocyanin in Vegetables

Table 2

Vegetable	Anthocyanin (mg/100g)	References
Red Cabbage	322	[45]
Red Radish	100-154	[45]
Red Onion	23.3-48.5	[48]
Eggplant	8-85	[49]

Flavonoids

The major active nutraceutical ingredients in plants are flavonoids. As is typical for phenolic compounds, they can act as potent antioxidants and metal chelators. They also have long been recognized to possess antiinflammatory, antiallergic, hepatoprotective, antithrombotic, antiviral, and anticarcinogenic activities. The best-described property of almost every group of flavonoids is their capacity to acts as antioxidants. The flavonoids block the Angiotensin-converting Enzyme (ACE) that is responsible for raising blood pressure [38]. In human beings, risk of myocardial infarction is reduced by taking high amount of anthocyanins [7]. Flavonoids are also helpful in protection of the vascular system [44]. Bioflavonoid, quercetin present in onion and garlic provides the protection against cancer and heart diseases.

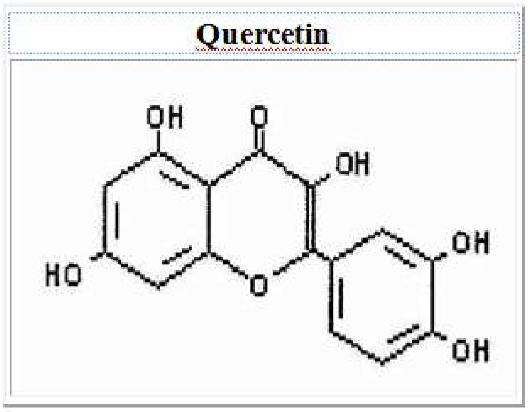

Figure 4

Isoflavones

This is a subclass of phenol found in beans and other legumes and its function is similar to flavonoids in effectively blocking enzymes promoting tumor growth. The important ones include genistein and daidzein which are found in soy products and the herb,*Pueraria lobata* [19]. Broad beans are rich in phyto-nutrients such as **isoflavone** and plant-sterols.

Glucosinolates

Glucosinolates convert to isothiocynates (contain sulfur) and indoles (contain no sulfur) when vegetables containing them are cut. They are high in cruciferous vegetables. The isothiocyanates, dithiolthiones and sulforaphane are the bio-transformation products of glucosinolates that are involved in blocking enzymes which are responsible for tumourous growth in liver, lung, breast and gastrointestinal tracts (esophagus, stomach and colon) [5]. Isothiocyanates are responsible for the hotness of horseradish, radish and mustard. Isothiocyanates are (-N=C=S) compounds. Allyl isothiocyanate is also called mustard oil. Phenethyl Isothiocyanate gives bitter taste to watercress. **Sulforaphane** especially rich in broccoli**,** causes cell cycle arrest and apoptosis of cancer cells**,** produces D-glucarolactone, a significant inhibitor of breast cancer, kills *Helicobacter_pylori* bacteria responsible for stomach ulcers and gastric cancer risk. Indole-3-Carbinol (I3C) most important indole in broccoli and cabbage, inhibits the human papilloma virus (HPV), which can cause uterine cancer**,** blocks estrogen receptors in breast cancer cells.

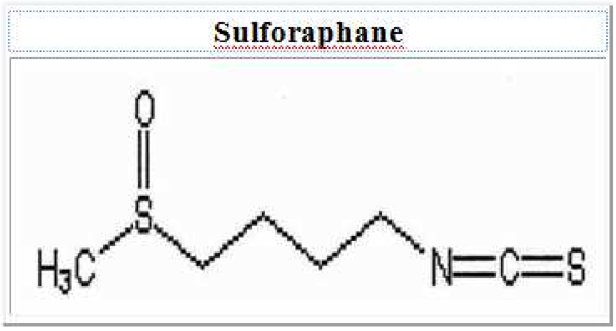

Figure 5

Thiosulfonates

Organosulfur phytochemicals in garlic and onions (garlic has more sulfur than onions), includes mercaptocysteines and allylic sulfides (an allyl is a hydrocarbon-sulfur bond), allylic sulfides contribute to the strong odor of garlic. Louis Pasteur in 1858 first noted antibacterial properties of garlic. Later on, in 1932 Albert Schweitzer treated amoebic dysentery in Africa with garlic [24]. Propanethial-S-oxide released from cut onions converted to sulfuric acid in eyes causes "burning", cooking garlic & onions destroys the enzyme allinase, preventing formation of beneficial sulfur compounds.

Lipoic Acid

Lipoic acid are antioxidants which can efficiently quench the hydroxyl radicals. They can protect catalase and glutathione, thus helpful in liver detoxification activities. Leafy green vegetables like spinach and broccoli have the highest concentrations of alpha-lipoic acid. It is found in the chloroplasts of the spinach cells. The chloroplasts in the cells produce the energy or glucose in the broccoli. Other green vegetables also contain alpha-lipoic acid, though not in the

concentrations found in leafy vegetables. The Linus Pauling Institute at Oregon State University lists peas, broccoli and Brussels sprouts as other vegetables containing alpha-lipoic acid [11].

Nasunin

The main natural source of nasunin is the skin of eggplants (Brinjal). It is also found in the purple radish, red turnip, and red cabbage. It is the substance that provides the dark pigment in the fruit of the eggplant. Its job is to protect the eggplant from environmental damage especially from the sun and other radiant sources of energy. The major type of anthocyanin in purple brinjal is nasunin and has the high antioxidant activity [35].

Prebiotics

Prebiotics are dietary ingredients that beneficially affect the host by selectively altering the composition or metabolism of the gut microbiota [54]. These are short-chain polysaccharides that have unique chemical structures that are not digested by humans; in particular fructose-based oligosaccharides that exist naturally in food or are added in the food. Vegetables like chicory roots, banana, tomato, alliums are rich in fructo-oligosaccharides.

IMPROVEMENT OF NUTRACEUTICAL VALUE OF VEGETABLES

Biotechnology and Plant Breeding

Biotechnology is a new, and potentially powerful, tool that has been added by most of the multinational private seed sector to their vegetable breeding programs. Transgenic crops, commonly referred to as genetically modified (GM) crops enable plant breeders to bring favorable genes, often previously inaccessible, into elite cultivars, improv-ing their value considerably and offer unique opportuni-ties for controlling insects, viruses and other pathogens, as well as nutritional quality and health benefits. Conven-tional plant breeding that utilizes non-transgenic approaches will remain the backbone of vegetable genetic improve-ment strategies. However, transgenic crop cultivars should not be excluded as products capable of contributing to more nutritious and healthy food.

Improvement of nutritional quality of horticultural crops including nutraceutical value of vegetable crops will be a rewarding activity for plant breeders as we enter the 21st century. In industrialized countries where sufficient food is available to most of the population, there is an increasing realization that nutritious food can play an important role in assuring a healthful life style and that eating is not solely for sustenance and body growth. People are beginning to consume more healthful foods that can alleviate problems related to “diseases of overabundance” and diet-related chronic diseases, such as some types of obesity, heart disease, and certain types of cancer (61). It is mainly the plant breeders, along with other agricultural researchers and extension services, who have provided the world’s population with plentiful food, improved health and nutrition and beautiful landscapes. The strategy of breeding for mineral and vitamin enhancement of vegetables has several complementary advantages. Most breeding and genetic effort has been directed to the crops which already are relatively rich vitamin sources including carrots, sweet potatoes, peppers, tomatoes, squash, pumpkins and melons. To develop commercial varieties of crops with enhanced nutrition, it may be essential to link nutrition to a commercial driver such as yield.

Anthocyanin in Tomato and Red Cabbage

Transgenic approaches have been taken to increase flavonoid levels in tomato fruit by overexpressing either the structural or regulatory genes involved in the biosynthetic pathway. Interspecific crosses with wild species transferred the

ability to produce small quantities of anthocyanins into the peel of cultivated tomatoes. For example, the dominant gene Anthocyanin fruit (*Aft*), which induces limited pigmentation upon stimulation by high light intensity, was introgressed into domesticated tomato plants by an interspecific cross with *S. chilense* [33, 17]. Similarly, the gene Aubergine (*Abg*), which was introgressed from *Solanum lycopersicoides* Dunal, can induce a strong and variegated pigmentation in the peel of tomatoes [33, 17]. Furthermore, the recessive gene atroviolacea (*atv*), derived from the interspecific cross with *Solanum cheesmaniae* (L. Riley) Fosberg, has been shown to stimulate strong anthocyanin pigmentation in the entire plant, particularly in vegetative tissues. Fruits with either *Aft* and *atv* alleles or *Abg* and *atv* alleles have been obtained and have generally shown a higher production of anthocyanins in the peel [13].

The transcriptional activation of a MYB and a bHLH transcription factor activate the expression of anthocyanin structural genes in mediating anthocyanin biosynthesis and accumulation in red cabbage [46].

Anthocyanin and Β- Carotene In Cauliflower

Purple cauliflower (*Brassica oleracea* var *botrytis*) is a very eye-catching vegetable and available commercially. The purple coloration is due to the accumulation of anthocyanins. Transcriptional regulation of structural genes appears to be a major mechanism by which anthocyanin biosynthesis is regulated in plants. *R2R3 MYB* and basic helix-loop-helix *(bHLH)* transcription factors as well as *WD40* proteins represent the three major families of anthocyanin regulatory proteins [26, 37]. An interesting and unique *Purple (Pr*) gene mutation in cauliflower (*Brassica oleracea* var *botrytis*) confers an abnormal pattern of anthocyanin accumulation, giving the striking mutant phenotype of intense purple color in curds and a few other tissues [8].

A spontaneous, semidominant Orange (*Or*) mutant in cauliflower (*Brassica oleracea* var *botrytis*) represents an interesting genetic mutation that confers carotenoid accumulation in normally unpigmented tissues [9]. The *Or* gene induces many tissues of the plant, most noticeably the white edible curd and shoot apical meristem, to accumulate high levels of b-carotene, turning them orange. Plants that are heterozygous for *Or* possess bright orange coloration in these tissues and exhibit normal growth, while *Or* homozygous plants produce smaller curds with stunted growth, presumably due to unknown pleiotropic effects [27].

Anthocyanin in Sweet Potato

In sweet potato, no *MYB*, *bHLH*, or *WD40* protein has been reported so far; instead, a MADS-box gene, *IbMADS10*, was recently isolated and suggested to be involved in anthocyanin pigmentation [23], although its involvement in the underground organ is unclear. Mano *et al*. reported the isolation of a new R2R3-type MYB gene, *IbMYB1*, from a purple-fleshed sweet potato cDNA library and its predominant expression in the tuberous roots of purple-fleshed cultivars [31]. The *IbMYB1* gene is responsible for purple pigmentation in the flesh of tuberous roots of sweet potato.

Lycopene in Tomato

Mehta *et al*. 2002, expressed a yeast S-adenosylmethionine decarboxylase gene (*ySAMdc; Spe2*) fused with a ripening-inducible E8 promoter to specifically increase levels of the polyamines spermidine and spermine in tomato fruit during ripening. The enhanced expression of the *ySAMdc* gene resulted in increased conversion of putrescine into higher polyamines and thus to ripening-specific accumulation of spermidine and spermine. This led to an increase in lycopene, prolonged vine life, and enhanced fruit juice quality. Lycopene levels in cultivated tomatoes are generally low, and increasing them in the fruit enhances its nutrient value.

Carotenoid in Potato, Sweet Potato and Tomato

Diretto, *et al*. (2006) have silenced the first step in the beta-epsilon branch of carotenoid biosynthesis, ly-copene epsilon cyclase (*LCY-e*) in potato—a tuber crop that contains low levels of carotenoids. This antisense tuber-specific silencing of the gene results in significant increases in carotenoid levels, with up to 14-fold more *β*-carotene. Cervantes-Flores, *et al*. (2010) have also recently reported in sweet potato the identification of quantitative trait loci (QTL) for dry matter, starch content and *β*-caro- tene content, opening up the possibility of genetic manipu-lation and further enhancement of this root crop.

To enhance the carotenoid content and pro-file of tomato fruit, Romer, *et al*. (2000) produced trans-genic lines containing a bacterial carotenoid gene (*crtI*) encoding the enzyme phytoene desaturase, which converts phytoene into lycopene. Expression of this gene in trans-genic tomato plants of the cultivar “Ailsa Cray” did not elevate total carotenoid levels. However, the *β*-carotene content increased about threefold, up to 45% of the total carotenoid content.

Organosulphur Compounds: Glucosinolates

Several epidemiological studies in Asia, the USA and Europe have suggested that the consumption of vegeta-bles from the *Brassicaceae* family, notably broccoli, re-duce the risk of lung, breast, colon, and prostate cancer. The phytochemicals thought to be responsible for these health benefits are the isothiocyanates sulphorap-hane and indole-3-carbinol. Sulphoraphane was initially thought to induce phase II enzymes in humans, which act against potentially carcinogenic compounds entering the body through the digestive system.

Chromosome segments from a wild ancestor, *Brassica villosa*, have been introgressed to enhance glucosinolate levels. *B. villosa* alleles determine whether hydrolysis generates indole-3-carbinol or sulphoraphane. Hence, highglucosi-nolate broccoli might be suitable for increasing the amount of sulphoraphane in the diet. The extent to which vegeta-ble brassicas protect against cancer probably depends on the genotype of the consumer, in particular the allele pre-sent at the *GSTM1* locus. This gene codes for the enzyme glutathione transferase, which catalyses the conjugation of glutathione with isothiocyanates. Approximately 50% of humans carry a deletion of the *GSTM1* gene [59], which reduces their ability to conjugate, process and excrete isothiocyanates. Individuals with two null alleles for *GSTM1* might gain less protection from these cultivars of vegetable. The most commonly consumed *Brassica* vegetable in Asia is *Brassica rapa*. *B. rapa* contains different isothiocyanates to *B. oleracea* and recent evidence suggests that individuals who are null for *GSTM1* can gain a protective benefit from *B. rapa* [58]. This example illus-trates another aspect of complexity in breeding for health functionality in vegetable crops: human genetic variabil-ity has not generally been considered in the context of plant breeding programmes, but it might have important im-plications. Thus, when establishing vegetable breeding targets, it is important to explore the extent to which human variability affects the bioavailability and processing of health-functional compounds and influences health outcomes for a particular commodity.

Gene List for Nutraceutical Enhancement in Vegetables

Table 3

Vegetable Crop	Gene	Nutrient Enhancement
Potato	*Or*	β-carotene
Cauliflower	*Or*	β-carotene
Potato	AmA_1	Protein
Potato	*Crt B*	β-carotene

Table 3: Contd.,		
Tomato	*B*	β-carotene
Sweet Potato	*asp-1*	High protein
Tomato	*Phytoene synthase -1(Psy-1)*	Carotenoids
Tomato	*chi-a*	High flavonols
Tomato	*LC and C1*	Kaempferol
Tomato	*Aft, Abg*	Anthocyanin
Cucumber	*Ore*	β-carotene
Red cabbage	*MYB*	Anthocyanin
Purple Cauliflower	*Pr*	Anthocyanin
Sweet Potato	*IbMYB1*	Anthocyanin
Tomato	*Cry-2*	Lutein
Tomato	*ySAMdc; Spe2*	Lycopene
Potato	*Dxs*	Phytoene
Tomato	*GCH1*	Folate
Lettuce	*Gch1*	Folate
Lettuce	*Pfe*	Iron
Lettuce	*Gul oxidase*	Ascorbate
Tomato	*hmgr-1*	Tcopherols

CONCLUSIONS

It is very imperative that the nutrients found in many foods, fruits and vegetables are responsible for the well documented health benefits. For example, lutein and zeaxanthin prevent cataracts and macular degeneration; beta-carotene and lycopene protect the skin from ultraviolet radiation damage; lutein and lycopene may benefit cardiovascular health, and lycopene may help prevent prostate cancer. Because of these and other marked health benefits of these, it must be taken regularly and to reduce the risk factors like high cholesterol, high blood pressure and diabetes. A great diversity of vegetables should be eaten to ensure that individual's diet includes a combination of phytonutriceuticals and to get all the health benefits. Regular consumption of a vegetable rich diet has undeniable positive effects on health since phytonutriceuticals of vegetables can protect the human body from several types of chronic diseases. Cruciferous vegetables, *Allium* sp, tomato, cucurbits, soybean, carrot, okra, underexploited vegetables like lettuce, coleus, sweet potato, yams, moringa, winged bean, basella, horse purslane, cluster bean etc are good sources of bioactive compounds. The molecular genetics and modern biotechnology approaches in conjunction with deciphering the metabolome of a crop plant are powerful tools that will help in specific redesigning of metabolism in food crops to accumulate desired, or close-to-the-desired, levels of a particular phytonutrient. Additional research is needed in many areas to ensure this emerging science continues to be valid and is translated rapidly into consumer-relevant products.

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